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SUBMARINE LANDSLIDES IN THE MISSISSIPPI RIVER DELTA

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ABSTRACT

Systematic side-scan sonar and high-resolution seismic records from the shallow-water offshore areas of the Mississippi Delta have revealed widespread subaqueous slope failures in bottom sediments. These failures have resulted in damage and loss to offshore structures and pipelines. The features occur on slopes with very low inclinations (ranging from 0.2° to 1.5°) and in water depths of 5-100 m. The types of features include collapse depressions, bottleneck slides, elongate slides and slumps, mudflow gullies, and overlapping mudflow lobes. Although movements include both vertical and rotational displacements, the basic mechanism can be approximated as downslope translation of shallow slabs of debris. Although movement rates of up to several hundred meters/year have been documented, it is postulated that large-magnitude surges may be inherent in these features. These submarine landslides result from complex temporal and spatial combinations of wave-induced stresses, sediment loading, and generation of high pore water and methane gas pressures.

INTRODUCTION

Numerous detailed marine surveys (high-resolution geophysical, side-scan sonar, and bathymetric data) have been conducted in the area offshore of the Mississippi River. These surveys have revealed the presence of a large number of distinct types of subaqueous slope instabilities that can be generally classed as submarine landslides. Most of these bottom sediment mass movements are of sufficient magnitude to severely endanger bottom-emplaced petroleum facilities such as offshore drilling and production platforms, wellheads, and pipelines.

The modern bird-foot (Balize) delta of the Mississippi River displays three major distributaries (Fig. 1) and has formed within the past 600-800 years.[1] Seaward progradation rates of the distributaries vary from in excess of 100 m/yr to less than 50 m/yr, depending upon the specific distributary monitored. Sedimentation rates seaward of the delta shoreline vary spatially as well as temporally. Near the mouths of the distributaries, accumulation rates in excess of 1 m/yr have been documented, whereas in adjacent interdistributary bays accumulation rates rarely exceed a few centimeters per year. In offshore waters, in front of the delta, accumulation rates vary from a few tens of centimeters per year in 50-m-depth water to a few millimeters per year in water depths approaching 200 m.

Offshore slopes of the entire delta front are extremely low, rarely exceeding 1.5°. In the interdistributary bays, bottom slopes are generally less than 0.5° and are rarely greater than 0.2°. In water depths of approximately 5-80 m, bottom slopes range from 0.7° to 1.5°, and in depths of 80-150 m the slopes are less than 1°. In general, hydrographic maps indicate extremely irregular topography, the bottom displaying a large number of radial trending submarine gullies[2] in water 20-80 deep and broad, flat terraces seaward to water depths as great as 200 m (Fig. 1).

The major characteristics of the Mississippi River delta and its continental shelf that influence the stability of bottom sediments include:

1. High rates of sedimentation result in excessive sedimentary loading (the water delivers annually approximately 6.6 x 10 metric tons to the coast).

2. Coarser grained sands and silts are deposited near the distributary mouth, and fine-grained silts and clays are deposited farther seaward in the distal offshore regions, causing differential loading of the underlying sediments.

3. The deltaic deposits display high water contents, generally low strengths, and, normally, underconsolidation.

4. Rapid biochemical degradation of organic material in the deposits results in formation of large quantities of in situ sedimentary gases, primarily methane and carbon dioxide.

5. The offshore region annually experiences winter storms or passage of hurricanes, which result in cyclic wave-loading processes.

Once subaqueous mass movements are initiated, the displaced debris often causes secondary types of instability. Detailed discussions of some of the characteristics of the Mississippi delta region can be found in Bennet et al.,[3] Coleman,[4] Suhayda et al.,[5] Whelan et al.,[6] Fisk and McClelland,[7] and Gade.[8]

SUBAQUEOUS LANDSLIDES IN MISSISSIPPI RIVER DELTA

The types of subaqueous landslides commonly encountered in the offshore Mississippi River delta include a) peripheral rotational slumps, b) collapse depressions, c) bottleneck slides, d) retrogressive elongate slides and mudflow gullies, and e) depositional lobes of mudflows. Previous literature discussing submarine failures in this region includes papers by Bea et al.,[9] Coleman et al.,[10] Coleman and Garrison,[11] Garrison,[12] Henkel,[13] Prior and Coleman,[14,15] Prior and Suhayda,[16] and Terzaghi.[17] Many of the subaqueous features display morphological characteristics that are similar to instabilities that have been documented in the subaerial environment, and it is possible to draw from these analogies some inferences concerning the mechanisms responsible for the formation of subaqueous failures. Papers by Hutchinson,[18] Hutchinson and Bhandari,[19] Hutchinson et al.,[20] Prior and Stephens,[21] Prior et al.,[22] and Skempton and Hutchinson[23] describe landslide failures in the subaerial environment and should be referred to for comparative purposes.

The main types of slope and sediment instability that have been mapped in 5- to 100-m water depths are illustrated schematically in Figure 2, which shows their distribution around a single distributary and part of an interdistributary bay. Similar spatial organization can be identified around the entire periphery of the modern Mississippi River delta. In the vicinity of the passes, rotational slumps are the most common feature, and in the shallow bays and offshore (5-20-m water depth) collapse depressions and bottleneck slides are the most common instability. Elongate retrogressive slides and coalescing mudflow gullies are the major instabilities on the delta front. The discharged remolded debris from the gullies spreads out as overlapping depositional lobes on the seaward end of the gullies. In many cases the seaward toe of the depositional lobe forms abrupt scarps on the sea floor, and pressure ridges and mud volcanoes form adjacent to the termination of the lobe.

Peripheral Rotational Slumps

The bottom slopes at the immediate mouths of the distributaries range from 0.2° to 0.6°, but often major scarps that display distinctly curved or curvilinear plan views scar these gentle slopes. The scarps vary in height from 3 to 8 m, exhibit slopes of 1°-4°, and often give the bar front a stairstepped appearance in profile view. Tensional crown cracks are often present upslope from the major scarp, and frequently small mud vents are associated with them. The vents normally occur as single small mud volcanoes and are formed by release, under pressure, of gas (methane), water, and fluid mud from within the sediments. The surface of the slump block normally displays extensive hummocky, irregular bottom topography and displaced blocks of sediment. In most instances the slump blocks have been downthrown and often rotated in an upslope direction, producing a recognizable reverse slope. Figure 3A shows in schematic form the most common morphological characteristics of these features. Figure 3B is a side-scan sonar record run across a series of slump features, the profile line running nearly parallel to the bottom slope. Note in this figure the distinct curved traces of the shear plane, the stairstepped appearance of the bottom, and the irregular topography on the seaward side of the slump region.

This type of morphology is indicative of rotational sliding over slightly curved shear planes that are concave upward. The multiple shear planes tend to merge at depth into a single basal shear surface that is inclined parallel to the sedimentary bedding. Displacements begin as shallow rotational slumps and continue over the basal shear as predominantly translational movements. The depth to the shear plane varies, but rarely exceeds 35 m. Movement rates are hard to determine specifically, but repeated surveys run approximately a year apart display movements ranging from a few hundred meters to nearly 1,000 m. Rapid sedimentary loading of the deposits by the annual deposition of flood material on the bar probably results in buildup of excess pore pressures, and some slight oversteepening of the bar front by annual deposition probably is the major mechanism responsible for the formation of this type of instability.

Collapse Depressions

Side-scan sonar records run in the shallow-water areas of the interdistributary bays and immediate offshore regions often reveal areas on the sea floor that are characterized by highly irregular and hummocky topography; these are "bowl-shaped" areas and are bounded by distinct scarps (Fig. 4B). It is obvious from fathometer data that the features represent depressions on the sea floor and that sediments have been displaced vertically. Bottom slopes in these regions are extremely low, ranging from <0.1° to 0.2°. The bottom sediments consist of soft, organic-rich clays containing large amounts (up to 15 percent) of methane gas.[5,24] These collapse depressions are relatively small by comparison to other mass movements in the delta, but can be extremely hazardous to pipelines and wellheads. The features range in size from 50 m to 150 m and have width to length ratios of 1 to 1.5. Scarps that completely encircle the feature rarely exceed 3 m in height. Figure 4A illustrates schematically the morphology of these features. The depressed central area of the collapse features displays irregular and hummocky topography, as seen in the side-scan sonar record illustrated in Figure 4B (two adjacent collapse depressions are shown). On the upslope margins, crown cracks often extend into the surrounding adjacent stable sediments, and on the downslope edge of the feature there is a shallow-angle reverse slope; occasionally a slightly raised rim of sediment is observed, indicating a tendency for downslope translatory movement. The depressed floors of the features often show no slope and are horizontal.

These features are interpreted to result from subsidence of parts of the sea floor. The amount of surface depressions varies from <1 to 3 m, and all data points to a decrease in the volume of the sediment, gas, and water system. It is highly probable that such volumetric changes are accomplished directly by loss of methane gas and pore water from the sediment at the instant of instability. Thus at the instant of failure the deposits would be in a state of liquefaction and essentially would not support any objects on the sea floor. The major factors responsible for producing these features are undoubtedly sedimentary loading by river deposition on the adjacent distributaries, cyclic loading by passage of storm waves,[5] and nearly continuous production of methane gases within the sediment by biochemical degradation of the incorporated organic material.

Bottleneck Slides

On slightly steeper slopes (0.2°-0.4°) in the shallow offshore Mississippi River delta are subaqueous instabilities that can generally be described as bottleneck landslides (Fig. 5A). These are similar morphologically to collapse depressions, except that the boundary scarps do not form a totally closed perimeter around the instability. On the downslope side of the feature, remolded debris is discharged over the surrounding stable sediments. This debris displays an undulatory surface of lobate shape and sometimes contains large rafted blocks of debris. The upslope edge is characterized by scarps (up to 3 m high) and is often complicated by numerous intersecting crown cracks. These slides vary in length from 150 to 600 m and have length/width ratios of 1.5-3.0. Figure 5A illustrates schematically the morphological features of this instability, and Figure 5B is a side-scan sonar record run across a feature that is approximately 200 m long and 130 m wide (~ 1.5 length/width ratio). The narrow bottleneck normally does not show up on features with this length/width ratio, but larger features that show the bottleneck are difficult to illustrate on a single side-scan sonar record.

These subaqueous features are morphologically similar to subaerial landslides, commonly associated with "quick clays." Skempton and Hutchinson (p. 300) assert, "There is one type of landslide which is peculiar only to quick clays, the 'bottleneck' type of retrogressive, multiple rotational failure." The characteristics they ascribe to this subaerial type of instability are similar in all respects to those mapped in the subaqueous environment. In this sort of slope instability there is both subsidence within the source area as material moves downslope and also the process of upslope retrogression, which enlarges the failure in an upslope direction, a phenomenon referred to as "spreading failure." Sediment strengths were very low at the time of failure. The basic mechanism, according to Skempton and Hutchinson,[23] can be summarized as follows: An initial failure takes place in which the material is remolded to the consistency of a liquid, which then flows out of the cavity, leaving the upslope scarp unsupported; further slumping takes place, and sediment flows out; these retrogressive slips continue until a stable scarp is attained. In the subaqueous environment high gas and pore-water pressures could build up to cause sudden and dramatic loss in sediment strength and lead to failure. The depth of the shear plane is presently unknown, but several lines of evidence, primarily morphological, indicate that it does not exceed 10-12 m below the sediment-water interface.

Elongate Retrogressive Slides and Mudflow Gullies

Extending radially seaward from each of the distributaries, in water depths of 10-100 m, are major elongate systems of sediment instability referred to as delta-front gullies[2] or mudflow gullies. These features are prominent enough to be mapped on regional hydrographic maps. From detailed surveys in numerous regions of the delta, it is apparent that these features emerge from the extremely disturbed areas of slump topography and that most have a recognizable area of rotational instability, or "head slump," at their upslope margins. Their morphology compares closely with that of subaerial mudslides and mudflows described in the subaerial environment.[22,25,20]

Each feature possesses a long, narrow chute or channel linking a depressed hummocky source area on the upslope end to composite overlapping depositional lobes or fans on the seaward end. Figure 6 schematically illustrates the major characteristic morphology of these features. The gullies are bounded by extremely abrupt linear escarpments that are arranged parallel or subparallel to each other . The floors of the gullies are composed of irregular, chaotic topography of blocks of debris of varying sizes. Figure 7A is a side-scan sonar record run at right angles across one of these gullies. The gully is approximately 450 m wide and has lateral scarp heights of approximately 9 m. Note the large, irregular blocks down the central axis of the gully. The gully floors are generally depressed from a few meters to 20 m below the adjacent intact bottom. The slopes of the gully side walls vary from 1° to as high as 19°, and often small rotational side slumps are apparent (Fig. 7A). Most of the chutes extend downslope at approximately right angles to regional depth contours and achieve lengths in excess of 8-10 km. They are rarely straight in plan view and display high sinuosity, with alternating narrow constrictions or chutes and wider bulbous sections (Fig. 8). Thus widths vary considerably, ranging from 20-50 m at the narrower sections to 600-800 m where the gullies are widest. In general the bottom slope of the gullies is steepest (1.0°-5.0°) in the wide, bulbous sections. Often adjacent gullies coalesce to form branching tributary systems whose plan view becomes extremely complex and requires overlapping side-scan sonar coverage for accurate mapping. The complexity of the chute areas can be seen in Figure 8, which shows a mapped region in the vicinity of Southwest Pass.

The development of elongate chutes of this type is very similar to that of subaerial debris flows[26] and subaerial mudflows.[25,18] The primary instability mechanisms in the source area of an elongate chute are similar to those described for bottleneck slides; i.e., subsidence is accompanied by downslope translatory movements of debris onto the surrounding slopes. In the elongate types, complex chutes develop and provide avenues for significant downslope transport of debris. The chutes are believed to develop as a direct result of loading by discharged debris onto the surrounding slopes. Rapid movements of large volumes of sediment out of the source area may provide sufficient localized loading of the buried sediments to cause failure. Hutchinson and Bhandari[19] refer to this process as "undrained loading"; it results in sediment strength loss as a consequence of high pore-water pressures in the buried sediment that are generated directly by the emplaced load. Such failures can therefore take place on slope angles that are lower than those involved in the primary failure, upslope. The presence of multiple head scarps (Fig. 6) and composite overlapping depositional lobes strongly suggests that these landslides are capable of reactivation and episodic activity, which would result in progressive retrogression upslope and extension downslope. Each phase of activity is accompanied by renewed localized loading until eventually the long profile of the entire feature is degraded below the ultimate angle of stability for the particular sediments.

Modes of movement within the gullies may be associated with "plug flow" characteristics[18] or occur as viscous slurry flow. In plug flow, velocities are similar across the chute and with depth, and flow occurs primarily as translational slab sliding, with the basal slip surface inclined approximately to the chute surface. In viscous slurry flow, laminar displacements of remolded low-strength sediment occur and are probably capable of transporting large blocks and clasts of debris. It is highly probable that the subaqueous chutes, similar to the subaerial ones, possess both these different modes of transport at different places within their overall geometry and alternate from one to another at different periods of activity. Of critical importance is the characteristic of such features to move episodically, with catastrophic pulses or surges.[21]

Depositional Lobes and Mudflow Noses

On the seaward ends of the elongate chutes are found broad overlapping composite depositional lobes (Figs. 6 and 8) that are composed of debris discharged from the gullies. Side-scan sonar records run in these extensive depositional lobes display bottom topography characterized by crenulated, blocky, disturbed debris and often abundant mud vents and volcanoes (Fig. 7B). Each lobe is composed of two morphological elements: an almost flat or gently seaward-inclined surface (<0.5°) and an abrupt distal scarp or "mud nose." These mud nose scarps vary in height from a few meters to in excess of 25 m and display slopes as high as 3°. In plan view (Fig. 8) the scarps are curved, and adjacent lobes often coalesce, forming an almost continuous but complex sinuous frontal scarp that may extend for distances of up to 20-25 km more or less parallel to bathymetric contours. The depositional areas may be composed of several overlapping lobes (out of the same chute or adjacent chutes) owing to periodic discharge events, and each discharge will be associated with its own distinctive nose. Seaward of the edge of the lobe are found extensive small-scale pressure ridges arranged sinuously and parallel. Commonly, large extensive fields of mud vents and volcanoes emitting gas, water, and fluid mud are found associated with the lobes and immediately seaward of the noses. These are undoubtedly the result of rapid loading of the underlying sediment by the depositional lobe, as well as consolidation processes within the debris itself.

The thicknesses of the lobes are often difficult to determine precisely, but each distinct lobe is normally on the order of 20-25 m thick. Because of overlapping, often the total thickness of the mudflow can approach 50-60 m. In one area of the delta at the shelf edge off South Pass, Coleman and Garrison[11] estimated that for one region, approximately 770 km^2, the volume of discharged debris was 11.2 x 10^6 m^3. This represents a large volume of debris to be transported across the shelf by subaqueous landslide processes. Movement rates are extremely difficult to document, but in some instances repeated surveys have shown that the lobes move forward in excess of 1,000 m in a year.[14] The downslope movement is often accompanied by oversteepening of the frontal slope, producing shallow rotational slumping and formation of large displaced blocks of debris on the seaward edge of the features.

FACTORS CONTRIBUTING TO SLOPE INSTABILITY

The analysis of precise mechanisms responsible for slope instability is a difficult task, and this is especially true of subaqueous failures on low-angle slopes such as documented from the Mississippi River delta. The features identified are the result of interaction of many variables rather than the product of any single factor. The Mississippi Delta offshore area is one of the most carefully documented of its type in the world, and yet information from bore logs, marine surveys, and monitoring of sea floor conditions is still insufficient for construction of a fully predictive model of instability processes.

The basic conditions for failure exist when stresses exerted on the sediment are sufficient to exceed its strength. This circumstance can be due to stress increases, sediment strength reduction, or a combination of the two.

Stresses

Although the general slope angles are small in the delta, they do constitute gravitational stresses on the sediment. Henkel[13] concluded that these stresses are unlikely to be sufficient to be the sole cause of failure, but this conclusion is clearly influenced by the assumptions made about strength properties at the moment of failure. Henkel[13] and Bea et al.[9] cited wave cyclic loading as another source of stress and suggested that this may be large enough for failure to occur. Suhayda et al.[5] have confirmed that substantial bottom pressures may be generated and that some landslides do occur at times of storm passage. However, instabilities also occur when wave stresses are low. Coleman et al.[10] ascribed the rotational slumps to oversteepening of the slopes near distributaries by annual flood deposition. This represents a localized increase in gravitational stresses. Rapid sedimentary loading by deposition emanating out of the distributaries also imposes significant stresses on the sediments.

Strength

Sediment strength at a potential failure surface is a function of cohesive and frictional forces, and these are strongly influenced by weight of sediment over the slip surface. The delta environment provides a number of conditions that may progressively alter the inherent strength properties, primarily by increasing the internal pressures that reduce the normal load. The highly water saturated sediments are likely to be subjected to excess pore-water pressures as a result of sedimentation rates in relation to consolidation rates. Terzaghi[17] related this process of pore-water pressure generation by sedimentary loading to delta-front gullies. Cyclic loading of the sediments by wave perturbation could be sufficient to cause localized pore-water pressure increases, which may lead to progressive strength reduction and eventually to failure.

The sediment/water system is further influenced by the internal generation of large amounts of biogenic methane gas. Whelan et al.[6] indicated values of up to 15 percent volume of methane in Mississippi River delta sediments. The exact effects of this process on sediment cohesion and friction are largely unknown, but it is likely that formation of gas bubbles in the pore water of sediment voids reduces the strength as the total gas and water pressure increases. All these factors point to the possibility that sediment strength in delta sediments can be highly variable both spatially and temporally. In normally consolidated marine sediments, shear strengths generally increase with depth and time owing to consolidation processes. In the delta setting, because of some of the factors cited, sediment strengths are highly variable at similar depths below the mudline, at different nearby sites, and at different times. In normally consolidated sediments, a single boring is often enough to characterize the strength properties of the region, but in the delta numerous borings are required; even with this control, the strengths could be expected to change dramatically with time (often short periods of time).

Thus the initiation of slope instability in the delta is rarely the result of a single causative mechanism, but more commonly represents a very complex interaction of processes operating on different time scales, and will produce failure with differing morphologies and magnitudes. The subaqueous failures described result from intricate combinations of factors that have been qualitatively discussed and summarized diagrammatically in Figure 9. It is emphasized that individual thresholds, when stresses exceed the strength of the material and failure occurs, are likely to be achieved by quite different combinations of the same basic factors over time and space. For example, storm waves may have a potentially greater effect if reduction in strength is well advanced by other factors than if strength characteristics have not been altered by these processes. Alternatively, rapid generation of in situ methane gas, or its mobility from one zone to another, may result in failure without any external changes in stress conditions. Until individual features are getter documented, detailed, and evaluated and their mechanisms, movement patterns, and material properties have been made, simplistic cause/effect statements should be avoided.

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REFERENCES

1. Fisk, H. N., Kolb, C. R., and Wilbert, L. G.: "Sedimentary framework of the modern Mississippi Delta," J. Sediment. Petrol. [1954] 24, 76-99.
2. Shepard, F. P.: "Delta-front valleys bordering the Mississippi distributaries," Geol. Soc. Amer. Bull. [1955] 66, No. 12, 1489-1498.
3. Bennet, R. H., Bryant, W. R., Dunlap, W. A., and Keller, G. H.: "Initial results and progress of the Mississippi Delta sediment pore water pressure experiment," Marine Geotechnology [1976] 1, 327-335.
4. Coleman, J. M.: Deltas: processes of deposition and models for exploration, Champaign, Ill. (Continuing Education Publication Co.) [1976] 102 p.
5. Suhayda, J. N., Whelan, Thomas, III, Coleman, J. M., Booth, J. S., and Garrison, L. E.: "Marine sediment instability: interaction of hydrodynamic forces and bottom sediments," OTC-2426, Eighth Annual Offshore Technology Conference, Houston, Tex. [1976].
6. Whelan, Thomas, III, Coleman, J. M., Roberts, H. H., and Suhayda, J. N.: "The occurrence of methane in recent deltaic sediments and its effects on soil stability," Bull. Internat. Assoc. Engr. Geol. [1976] 14, 55-64.
7. Fisk, H. N., and McClelland, B.,: "Geology of continental shelf off Louisiana: Its influence on offshore foundation design," Geol. Soc. Amer. Bull. [1959] 70, No. 10, 1369-1394.
8. Gade, H. G.: "Effects of a non-rigid impermeable bottom on plane surface waves in shallow water," J. Mar. Res. [1958] 16, No. 2, 61-82.
9. Bea, R. G., Bernard, H. A., Arnold, P., and Doyle, E. H.: "Soil movements and forces developed by wave-induced slides in the Mississippi Delta," J. Petrol. Tech. [April, 1975] 500-514.
10. Coleman, J. M., Suhayda, J. N., Whelan, Thomas, III, and Wright, L. D.: "Mass movements of Mississippi River delta sediments," 24th Conference Gulf Coast Assoc. Geol. Soc., Lafayette, La. [1974] 49-68.
11. Coleman, J. M., and Garrison, L. E.: "Geological aspects of marine slope instability, northwestern Gulf of Mexico," Marine Geotechnology [in press].
12. Garrison, L. E.: "The instability of surface sediments on parts of the Mississippi delta front," U. S. Geol. Survey, Open File Report, Corpus Christi, Tex. [1974] 18 p.
13. Henkel, D. J.: "The role of waves in causing submarine landslides," Geotechnique [1970] 20, 75-80.
14. Prior, D. B., and Coleman, J. M.: "Disintegrating, retrogressive landslides on very low angle subaqueous slopes, Mississippi Delta," Marine Geotechnology [in press a].
15. Prior, D. B., and Coleman, J. M.: "Submarine landslides on the Mississippi delta front slope," Geoscience and Man, School of Geosciences, Louisiana State Univ., Baton Rouge [in press b].
16. Prior, D. B., and Suhayda, J. N.: "Application of infinite slope analysis to subaqueous sediment instability, Mississippi Delta," [submitted to Engineering Geology].
17. Terzaghi, K.: "Varieties of submarine slope features," Eighth Texas Conference Soil Mech. and Foundation Engr. [1956] No. 29, 40 p.
18. Hutchinson, J. N.: "A coastal mudflow on the London clay cliffs at Beltinge, North Kent," Geotechnique [1970] 20, 412-438.
19. Hutchinson, J. N., and Bhandari, R. K.: "Undrained loading, a fundamental mechanism of mudflows and other mass movements," Geotechnique [1971] 21, 353-358.
20. Hutchinson, J. N., Prior, D. B., and Stephens, N.: "Potentially dangerous surges in an Antrim mudslide," Quart. J. Engr. Geol. [1974] 7, 363-376.
21. Prior, D. B., and Stephens, N.: "Some movement patterns of temperate mudflows: examples from north-east Ireland," Geol. Soc. Amer. Bull. [1972] 83, 2533-2544.
22. Prior, D. B., Stephens, N., and Archer, D. R.: "Composite mudflows on the Antrim coast of north-east Ireland," Geografiska Annaler [1968] 50, 65-78.
23. Skempton, A. W., and Hutchinson, J. N.: "Stability of natural slopes and embankment foundations," Seventh Internat. Conf. Soil Mech., Mexico, State-of-the-Art volume [1969] 291-340.
24. Roberts, H. H., Cratsley, D. W., and Whelan, Thomas, III: "Stability of Mississippi Delta sediments as evaluated by analysis of structural features in sediment borings," OTC-2425, Eighth Annual Offshore Technology Conference, Houston, Tex. [1976].
25. Prior, D. B.: "Coastal mudslide morphology and processes in Eocene clays in Denmark," Dansk Geografisk Tiddskrift [in press].
26. Johnson, A. M.: Physical processes in geology, San Francisco (Freeman) [1970].

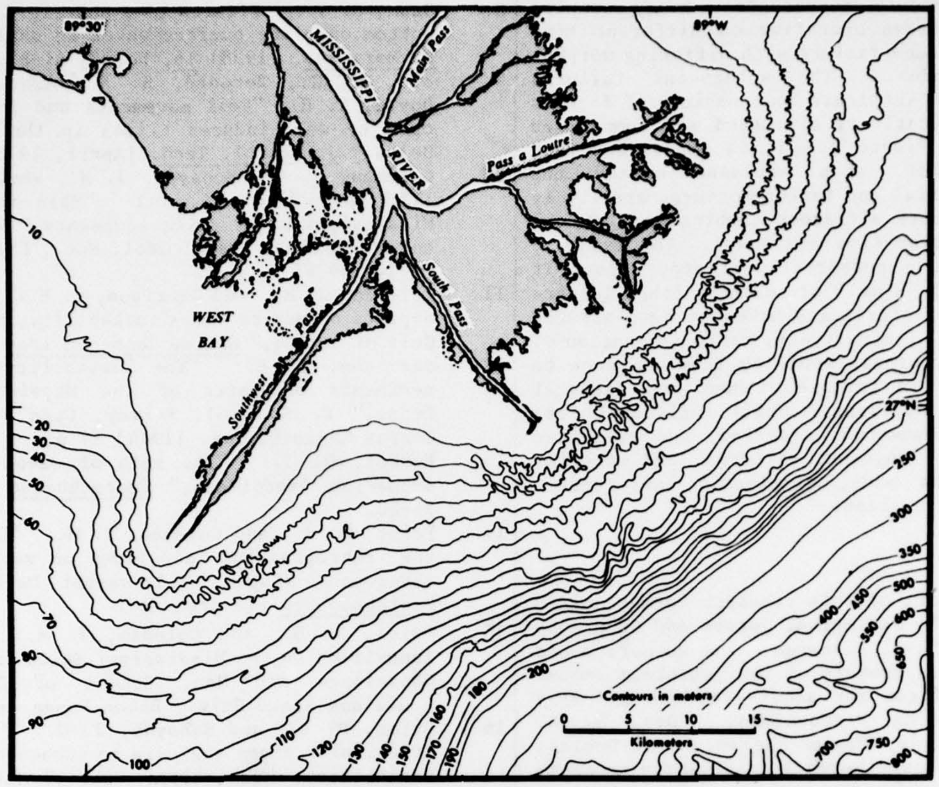

Fig. 1 - Generalized bathymetry of the modern birdfoot delta, Mississippi River.

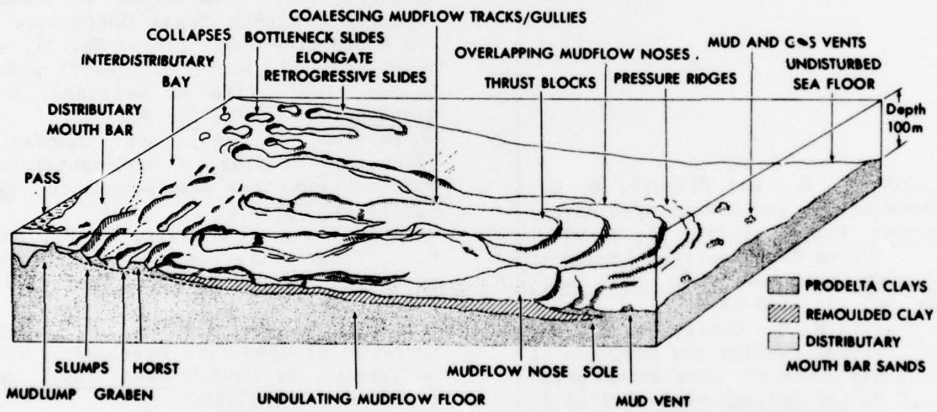

Fig. 2 - Schematic distribution and morphology of subaqueous landslides in the vicinity of a distributary and offshore, Mississippi River delta.

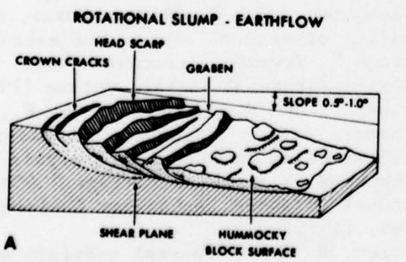

Fig. 3a - Schematic representation of the morphology of rotation slump.

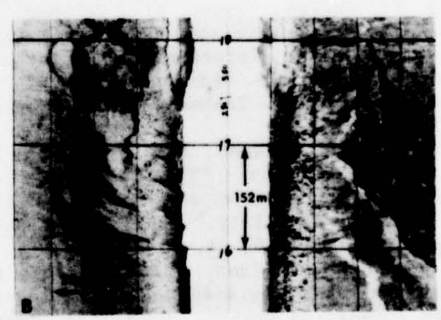

Fig. 3b - Side-scan sonar record run across a series of rotational slumps, Mississippi River delta.

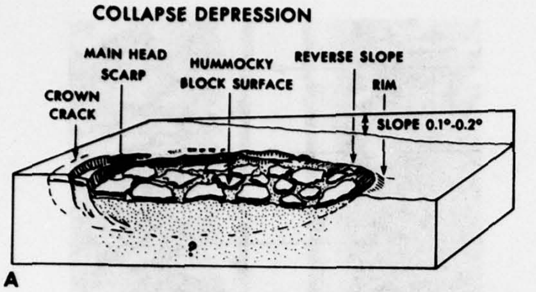

Fig. 4a - Schematic representation of the morphology of a collaspe depression failure.

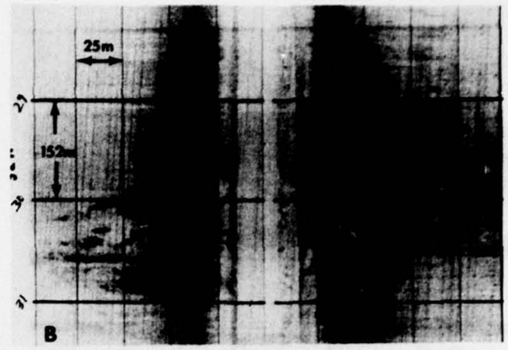

Fig. 4b - Side-scan sonar record run across two small collaspe depressions in an interdistributary bay, Mississippi River.

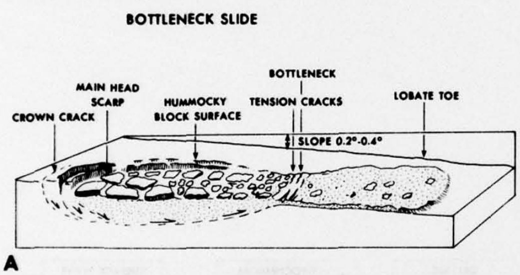

Fig. 5a - Schematic representation of the morphology of a bottleneck slide failure.

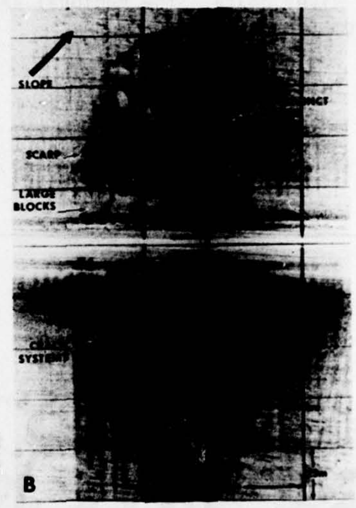

Fig. 5b - Side-scan sonar record run across a small bottleneck failure off South Pass, Mississippi River.

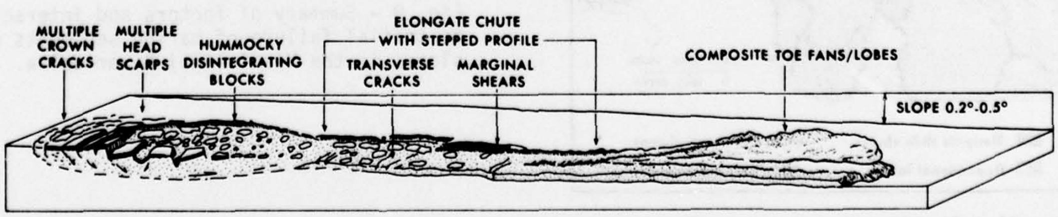

Fig. 6 - Schematic representation of the morphology of an elongate retrogressive slide and depositional lobe.

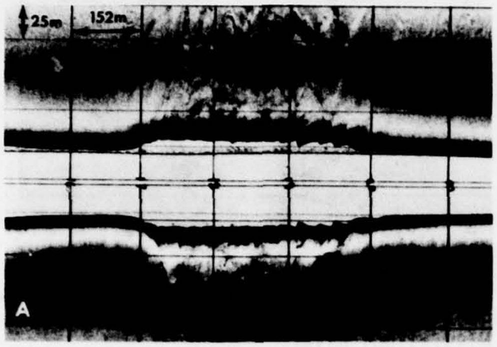

Fig. 7a - Side-scan sonar record run across the narrow chute of an elongate retrogressive slide, Mississippi River delta. The regional seaward slope is from top to bottom.

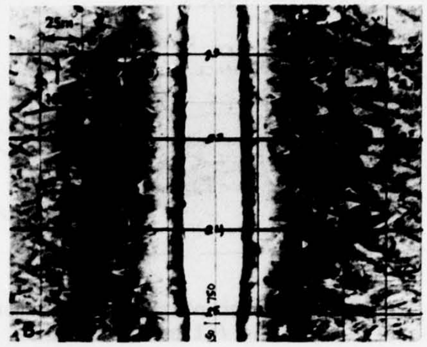

Fig. 7b - Side-scan sonar record run across a portion of an extensive depositional lobe discharged from an elongate chute. Regional slope from right to left.

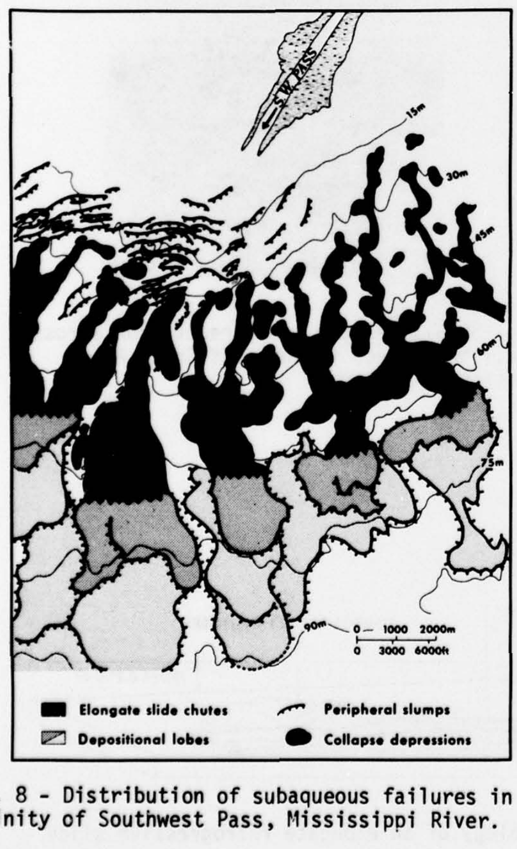

Fig. 8 - Distribution of subaqueous failures in the vicinity of Southwest Pass, Mississippi River.

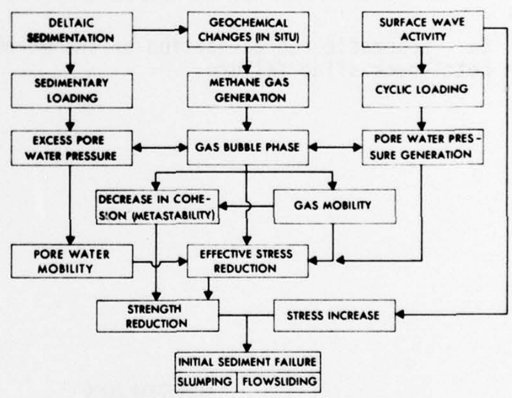

Fig. 9 - Summary of factors and interactions leading to initial failure of marine sediments on low angle slopes in the Mississippi River delta.

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13. ABSTRACT

Systematic side-scan sonar and high-resolution seismic records from the shallow-water offshore areas of the Mississippi Delta have revealed widespread subaqueous slope failures in bottom sediments. These failures have resulted in damage and loss to offshore structures and pipelines. The features occur on slopes with very low inclinations (ranging from 0.2° to 1.5°) and in water depths of 5-100 m. The types of features include collapse depressions, bottleneck slides, elongate slides and slumps, mudflow gullies, and overlapping mudflow lobes. Although movements include both vertical and rotational displacements, the basic mechanism can be approximated as downslope translation of shallow slabs of debris. Although movement rates of up to several hundred meters/year have been documented, it is postulated that large-magnitude surges may be inherent in these features. These submarine landslides result from complex temporal and spatial combinations of wave-induced stresses, sediment loading, and generation of high pore water and methane gas pressures.

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